



Severity of foraminal lumbar stenosis and the relation to clinical symptoms and response to periradicular infiltration - introduction of the "melting sign"

Farshad, Mazda ; Sutter, Reto ; Hoch, A

Abstract: **BACKGROUND CONTEXT:** Nerve root compression causing symptomatic radiculopathy can occur within the intervertebral foramen. Sagittal MRI sequences are reliable in detection of nerve root contact to intraforaminal disc material, but a clinically relevant classification of degree of contact is lacking. **PURPOSE:** To investigate a potential relation of amount of contact between intraforaminal disc material and nerve root to clinical findings and response after periradicular corticosteroid infiltration. **STUDY DESIGN:** Post hoc analysis of a prospective cohort. **PATIENT SAMPLE:** Patients who underwent CT-guided periradicular corticosteroid infiltration (L1 - L5) at our institution (01/2014 - 05/2016) were included. **OUTCOME MEASURES:** The medical records and radiographic imaging were reviewed. **METHODS:** T2-weighted MR images of the lumbar spine of patients with single level symptomatic radiculopathy with (responders, n=28) or without (non-responders, n=14) pain relief after periradicular infiltration with corticosteroids were measured and compared by two independent readers to determine the amount of intraforaminal nerve root contact with the intervertebral disc ("melting" of the T2-hypointense signal). Pain relief was defined with a pain level decrease of >50% on a visual analogue scale and lack of pain relief with a pain level decrease of <25%, respectively. The amount of T2-hypointensity melting of disc and nerve root was categorized to 0%, 1-25%, and over 25%. Nothing to disclose. **RESULTS:** Reader one identified 0% T2-melting in none of the responders, 1-25% melting in 13 (46.4%) patients, 26-50% in 15 (53.6%) of the 28 patients with pain relief after periradicular corticosteroid infiltration (responders) with a mean amount of T2-melting of 5.9 ± 2.1 mm. Whereas the non-responder group had 0% T2-melting in 2 (14.3%) patients, 1 - 25% T2-melting in 11 (78.6%) patients and 26 - 50% in 1 (7.1%) patient with a mean amount of T2-melting of 2.6 ± 1.9 mm ($p < 0.05$). Reader two identified 0% T2-melting in none, 1-25% T2-melting in 15 (53.6%) patients and 26-50% in (46.4%) 13 of the 28 responders, with mean amount of 6.3 ± 1.9 mm. In the non-responder group 0% T2-melting was seen in 3 (21.4%) patients, 1 - 25% T2-melting in 10 (71.4%) patients and 26 - 50% in 1 (7.1%) patient with a mean amount of T2-melting of 2.7 ± 1.9 mm ($p < 0.05$). None of the MR images showed T2-melting in over 50 percent of the circumference of the intraforaminal nerve root. A T2-melting of >25% had a high specificity of 93% but a sensitivity of 50%, thus a positive likelihood ratio of 7.5, to identify those with a pain relief of more than 50% after infiltration. **CONCLUSION:** The amount of T2-melting of disc material and nerve root on sagittal MRI (>25%) predicts the amount of pain relief by periradicular infiltration in patients with intraforaminal nerve root irritation.

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Severity of foraminal lumbar stenosis and the relation to clinical symptoms and response to periradicular infiltration – Introduction of the “melting sign”

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Abstract

Background Context

Nerve root compression causing symptomatic radiculopathy can occur within the intervertebral foramen. Sagittal MRI sequences are reliable in detection of nerve root contact

to intraforaminal disc material, but a clinically relevant classification of degree of contact is lacking.

Purpose

To investigate a potential relation of amount of contact between intraforaminal disc material and nerve root to clinical findings and response after periradicular corticosteroid infiltration.

Study Design

Post hoc analysis of a prospective cohort.

Patient Sample

Patients who underwent CT-guided periradicular corticosteroid infiltration (L1 – L5) at our institution (01/2014 - 05/2016) were included.

Outcome Measures

The medical records and radiographic imaging were reviewed.

Methods

T2-weighted MR images of the lumbar spine of patients with single level symptomatic radiculopathy with (responders, n=28) or without (non-responders, n=14) pain relief after periradicular infiltration with corticosteroids were measured and compared by two independent readers to determine the amount of intraforaminal nerve root contact with the intervertebral disc (“melting” of the T2-hypointense signal). Pain relief was defined with a pain level decrease of >50% on a visual analogue scale and lack of pain relief with a pain level decrease of <25%, respectively. The amount of T2-hypointensity melting of disc and nerve root was categorized to 0%, 1-25%, and over 25%. Nothing to disclose.

Results

Reader one identified 0% T2-melting in none of the responders, 1-25% melting in 13 (46.4%) patients, 26-50% in 15 (53.6%) of the 28 patients with pain relief after periradicular corticosteroid infiltration (responders) with a mean amount of T2-melting of 5.9 ± 2.1 mm. Whereas the non-responder group had 0% T2-melting in 2 (14.3%) patients, 1 – 25% T2-melting in 11 (78.6%) patients and 26 – 50% in 1 (7.1%) patient with a mean amount of T2-melting of 2.6 ± 1.9 mm ($p < 0.05$).

Reader two identified 0% T2-melting in none, 1-25% T2-melting in 15 (53.6%) patients and 26-50% in (46.4%) 13 of the 28 responders, with mean amount of 6.3 ± 1.9 mm. In the non-responder group 0% T2-melting was seen in 3 (21.4%) patients, 1 – 25% T2-melting in 10 (71.4%) patients and 26 – 50% in 1 (7.1%) patient with a mean amount of T2-melting of 2.7 ± 1.9 mm ($p < 0.05$). None of the MR images showed T2-melting in over 50 percent of the circumference of the intraforaminal nerve root. A T2-melting of $>25\%$ had a high specificity of 93% but a sensitivity of 50%, thus a positive likelihood ratio of 7.5, to identify those with a pain relief of more than 50% after infiltration.

Conclusion

The amount of T2-melting of disc material and nerve root on sagittal MRI ($>25\%$) predicts the amount of pain relief by periradicular infiltration in patients with intraforaminal nerve root irritation.

Keywords: Foraminal Stenosis; Lumbar Spine; Disc Herniation; Sagittal MRI; Nerve Root; Periradicular Infiltration; Melting Sign

1 Introduction

2 Compression of the nerve root by degenerated disc material, bone or ligaments can cause a
3 radiculopathy. In the lumbar spine, the compression is commonly located within the spinal
4 canal either median, paramedian or recessal causing radiculopathy of the descending nerve
5 root [1-4]. However, radiculopathy can also be caused by compression of the exiting nerve
6 root within the neural foramen, usually due to a disc herniation. Several proposals were
7 made for description and documentation of disc herniation and nerve root compression within
8 the spinal canal [5-9]. However, only few classifications address the less commonly seen
9 nerve root contact/compression by surrounding structures in the neural foramen and a
10 clinically relevant correlation seems still lacking [10-12]. Once compression of the nerve root
11 within the neural foramen causes painful radiculopathy without neurological deficits, patients
12 are typically treated first by conservative therapeutic measures such as corticosteroid
13 infiltrations. While the effect of corticosteroid infiltrations in regard to pain relief is well
14 investigated for radiculopathy caused by paramedian disc herniations [13-16] and has found
15 an important role in the conservative treatment strategies, pain relief by injection of
16 corticosteroids around nerve roots that are compressed within the neural foramen is not well
17 predictable.

18
19 The objective of this study was to quantify the amount of contact of the intervertebral disc
20 with the nerve root within the intervertebral foramen by investigating the total and relative
21 amount of the circumference of the nerve root that has contact to the degenerated or
22 herniated disc on T2-weighted sagittal MRI series ("T2-melting") and to illuminate potential
23 associations to clinical symptoms and response to periradicular corticosteroid infiltrations.

Material and Methods

Study population

After approval of the responsible ethical committee, a post hoc analysis of a prospective cohort was conducted to identify consecutive patients seen in the outpatient clinic from May 2014 to December 2015 with a symptomatic single level radiculopathy of a lumbar nerve root (L1 – L5) and pain relief of more than 50 percent one month after CT-guided periradicular infiltration of the affected nerve root (responders, 18 men and 10 women, mean age 61.9 years, range 29 - 79 years) or pain relief of less than 25 percent (non-responders, 5 men and 9 women, mean age 59.1 years, range 28 - 76 years) (Table 1). Patients with an intermediate pain relief of 26-49% were a-priori not allocated into the study groups to allow a clear distinction between responders and non-responders to peri-radicular infiltration. Exclusion criteria were clinical symptoms of a radiculopathy on more than one level, multiple periradicular infiltrations, nerve root compression on a location other than intraforaminal in the MR images (median, paramedian, recessal, extraforaminal), advanced degenerative spinal alterations (e.g. degenerative scoliosis, severe listhesis, etc..), malignancy or pregnancy. The maximal time period between periradicular infiltration and prior MR images for inclusion in either group was six months. The diagnosis of a symptomatic radiculopathy (with or without altered sensibility or motor deficits) was documented by experienced spine surgeons in our clinic based on the clinical examination. Periradicular infiltration was performed by experienced radiologists and was executed under CT-control: After inserting a 21G needle, the position of the needle was verified by injecting iodine contrast (1ml iopamidol 200 mg/ml) under a CT control, then a local anesthetic (1ml ropivacaine 0.2%) and a corticosteroid (1ml triamcinolone 40mg/ml) were injected and the correct positioning of the needle was controlled again with CT.

Amount of pain relief was assessed before and one month after periradicular infiltration on a visual analogue scale (VAS) from 0 – 10, with 10 being the maximal pain level. The alteration was quantified in percent. Follow up to survey was 100% after one month.

MR Imaging

MR imaging of the lumbar spine was performed with a 1.5 Tesla imager (Avanto; Siemens Medical Solutions, Erlangen Germany). All 42 examinations acquired in the 42 patients were obtained within our standard protocol for lumbar spine and covered the segments Th11 to S2. The images of interest were the sagittal T2-weighted images, the axial images were only used for determination of the correct side. The T2-weighted series were obtained with the following parameters: echo time (TE) 115ms, repetition time (TR) 3800ms, matrix 358 x 512, field of view 300 x 300mm, slice thickness 4mm, intersection gap 0.4mm. The imaging protocol conformed to the standards of the American College of Radiology.

Quantification of amount of nerve root compression within the neural foramen

T2-weighted sagittal MR image of the lumbar spine were used to quantify the total and relative amount of nerve root contact/compression within the neural foramen. In T2-weighted sagittal MRI series the nerve root appears hypointense, as does the intervertebral disc. In absence of a compression, the nerve root is completely surrounded by perineural fat which is hyperintense, thus creating a clear contrast. In presence of a bulging, protrusion or extrusion of the disc a contact occurs between these two hypointense structures (disc and nerve root), which gives the impression of a “melting” of structures – this phenomenon was defined as the “T2-melting”.

The total (in mm) and relative (in %) amount of T2-melting sign was documented in each of the responder and non-responder patients by two independent readers (an experienced

board certified musculoskeletal radiologist (R.S.) and an orthopedic resident (A.H.)).

Examinations were reviewed in a randomized fashion and the readers were blinded to the clinical outcome of the periradicular infiltration.

Statistical Analysis

All data were documented with the REDCap software (Research Electronic Data Capture, Vanderbilt University, Nashville, Tennessee, USA). Statistical analyses were used to describe descriptive data as mean and SD as well as ranges were appropriate.

Five groups were formed for statistical analysis a-priori based on the amount of T2-melting of the nerve root to the degenerated/herniated disc (Figure 1): no T2-melting at all, T2-melting of 1 – 25 percent (Figure 2) of the circumference, T2-melting of 26 – 50 percent (Figure 3), of 51 – 75 percent and of 76 – 100% of the circumference. In the post-hoc analysis, the five groups were consolidated to three groups by eliminating the last two groups since none of the patients had a T2-melting of >50%. Contingency table was used to find the sensitivity, specificity and positive likelihood ratio of a T2-melting of >25% defined as a positive test for prediction of a pain relief effect of >50% after infiltration. Interreader reliability of more or less than 25% T2-melting was assessed via Intraclass correlation coefficient (Kappa coefficient) with absolute agreement reporting the average measures. Statistical significance of association of the binary outcome variables T2-melting sign and pain relief was tested using Pearson's chi-square test. Statistical analysis was performed using SPSS (IBM Corp. IBM SPSS Statistics for Windows, Version 23.0.0.0. Armonk, NY: IBM Corp.) Significance was set at $p < 0.05$.

Results

The “melting sign”, referring to >25% of T2-melting of the nerve root to the herniated disc as a test to predict pain relief of more than 50% one month after periradicular infiltration, achieved a specificity of 93% (both reader), and a mean sensitivity of 50% (reader 1: 54% and reader 2: 46%) (Figure 4) and a positive predictive value of 93% (both reader) with a likelihood ratio of 7.5. There was a significant association between the presence or absence of a T2-melting sign and 1 month postoperative pain relief (Yes/No) for both readers (Reader one: $\chi^2(1) = 8.53$, $p = 0.003$, Reader two: $\chi^2(1) = 6.48$, $p = 0.011$). The odds of successful pain relief were 15.0 (Reader one, 95% CI: [1.7; 130.8]) and 11.3 (Reader two, 95% CI: [1.3; 98.2]) times higher if T2-melting sign was positive than if T2-melting sign was negative.

The interreader reliability presented with a κ coefficient of 0.744.

The location of the nerve root compression was L1 0 patients, L2 1 patient (3.6%), L3 4 patients (14.5%), L4 7 patients (25%), L5 16 patients (57.1%) in the responder group and L1 0, L2 1 patient (7.1%), L3 2 patients (14.3%), L4 2 patients (14.3%), L5 9 patients (64.3%) in the non-responder group.

In the responder group, reader one and two detected zero patients with no T2-melting at all. Reader one detected 13 patients (46.4%) with a T2-melting of 1 – 25% of the circumference of the nerve root, reader two detected 15 patients (53.6%) in this category. Reader one detected 15 patients (53.6%) and reader two 13 patients (46.4%) with T2-melting of 26 – 50%. None of the readers documented a T2-melting of more than 50%. In the non-responder group the following results were obtained: reader one: no T2-melting in 2 patients (14.3%), 1 – 25% T2-melting in 11 patients (78.6%), 26 – 50% T2-melting in 1 patient (7.1%) and reader two: no T2-melting in 3 patients (21.4%), 1 – 25% T2-melting in 10 patients (71.4%) and 26 – 50% in 1 patient (7.1%).

The smallest amount of T2-melting detected by reader one was 1.8 millimeters in the responder group and 0 millimeter in the non-responder group, whereas reader two detected 1.9 millimeters and 0 millimeter, respectively. The largest amount of T2-melting detected by reader one was 10.8 millimeters in the responder group and 6.5 millimeters for the non-responder group, whereas reader two detected 10.4 millimeters and 6.0 millimeters, respectively.

The mean T2-melting measured by reader one was 5.9 millimeters (SD 2.1mm) for the responder group and 2.6 millimeters (SD 1.9mm) for the non-responder group ($p < 0.001$). Reader two measured 6.3 millimeters (SD 1.9mm) and 2.7 millimeters (SD 1.9mm) ($p < 0.001$), respectively.

In the responder group the mean pain level before periradicular infiltration was 6.0 on the visual analogue scale (VAS) compared to 5.6 in the non-responder group ($p = 0.535$). One month after periradicular infiltration the mean pain level in the responder group was 1.3 whereas no relevant alteration of the pain level with stagnation on VAS 5.6 was documented in the non-responder group ($p < 0.05$). The mean amelioration of pain was - 4.7 (-78.3%) in the responder group compared to none in the non-responder group.

According to reader one the mean amelioration in pain of the group with a T2-melting of 1 – 25% was VAS 4.3 and with 26 – 50% of T2-melting it was VAS 5.0, which was comparable to reader two with VAS 4.3 and 5.1, respectively.

In the responders there were five patients with a sensory radiculopathy, two of them showed a T2-melting of 1 – 25% of the circumference of the nerve root and three of 26 – 50% according to both readers. One month after periradicular infiltration one patient showed a relief of the sensory deficit; this patient showed a T2-melting of 26 – 50%. Two patients showed a persistence of the sensory deficit and in two patients no assessment of the sensory status was obtained one month after periradicular infiltration.

In the same group, there were six patients with a motoric deficit, three of them showed a T2-melting of 1 – 25% and three a T2-melting of 26 – 50% according to reader one and two with

a T2-melting of 1 – 25% and four with a T2-melting of 25 – 50% according to reader two, respectively. One month after periradicular infiltration two patients showed reliefs of the motoric deficits, both were in the group of a higher T2-melting according to both readers. Two patients showed a persistence of motor weakness and in two patients no assessment of the motor status was obtained one month after periradicular infiltration.

Discussion

A method for quantification of the amount of contact of the intervertebral disc with the nerve root within the intervertebral foramen with investigation on potential clinical correlation regarding radiculopathic symptoms and reaction to periradicular corticosteroid infiltration was lacking and therefore object of this study.

We investigated the total and relative amount of the circumference of the nerve root that had contact to the herniated disc at the neural foramen on T2-weighted sagittal MR images (“T2-melting”) in patients with symptoms of radiculopathy and found that a certain amount of “T2-melting” is associated with response to periradicular corticosteroid infiltration. A T2-melting of the nerve root of >25% showed a positive predictive value of 93% in regard of pain relief after infiltration. This finding is plausible, as mechanical irritation of a nerve root is the main reason causing the clinical picture of a symptomatic radiculopathy [17-19]. Although mechanical irritation of the nerve at the foramen can be caused by different structures including degenerative facet joints, approaching pedicles (bony neuroforaminal stenosis), ligaments and even tumors, still the majority of radiculopathies are caused by disc protrusions, -bulging and -herniations. The focus has so far been most commonly on nerve root compression within the intraspinal canal [4-9]. Only a few authors reported about the clinical and radiological findings of intraforaminal nerve root irritation [10-12]; Wildermuth et al. proposed a grading system with 4 grades; grade 0 indicates a normal intervertebral foramen, grade 1a deformity of the perineural fat and a mild foraminal stenosis, grade 2a partial obliteration of the perineural fat and a moderate foraminal stenosis and grade 3 an obliteration of the

perineural fat and nerve root collapse [11]. Lee et al. suggested also a grading system with 4 grades; grade 0 indicates a normal intervertebral foramen, grade 1a mild foraminal stenosis with perineural fat obliteration in either transverse or vertical direction, grade 2a moderate foraminal stenosis with perineural fat obliteration in both transverse and vertical direction and grade 3 severe foraminal stenosis with nerve root collapse or morphologic change [10]. Both proposed classifications seem to have a interobserver reliability with a κ value around 0.73-0.77 and a correlation to neurological symptoms of around 0.7. Both gradings were, in contrast to the here proposed T2-signal melting in sagittal MRI, not based on clinical consequences such as response to periradicular infiltrations and are therefore less likely to find clinical relevance.

The proposed T2-melting of >25% defined as a positive test achieved a high specificity for pain reduction after corticosteroid infiltrations with 93% while being a reliable method with an interreader reliability of 0.744. Since a higher degree of melting (e.g. >50%) was not documented in any patient within the here investigated group, further research is needed to investigate the effect of periradicular injections in such patients. Although subject of further investigation, we suspect that the amount of T2-melting will also correlate with clinical outcomes of decompression as there seems to be an association of pain relief achieved with periradicular infiltration and surgical decompression [20].

We believe that although limitations of this study such as the post hoc analysis of a prospective cohort design without the possibility to match the non-responder group and the relative small number of patients due to the strict inclusion criteria to limit biases demands further studies, the plausibility of the method of quantification, namely the amount contact of the nerve root to the disc herniation succeeded to find clinical correlation.

Conclusion

The amount of T2-melting of disc and nerve root on sagittal MR images predicts the amount of pain relief one month after periradicular infiltration in patients with intraforaminal nerve root irritation.

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Figure 1, Schematic illustration of different amounts of “T2-melting” of discus material with the nerve root on sagittal T2 MRI.

Figure 2, T2 sagittal MRI of a 48 year old female patient with a “T2-melting” of > 25% of the L4 nerve root.

Figure 3, T2 sagittal MRI of a 64 year old male patient with a “T2-melting” of < 25% of the L5 nerve root.

Figure 4, Percentage of positive or negative T2-Melting (>25%) in responders or non-responders to periradicular infiltrations according to reader one and two, respectively.

Table 1, Patients characteristics.

	Responders	Non-Responders	Total (%)
N	28	14	42 (100)
Gender			
Male	18	5	23 (54.8)
Female	10	9	19 (45.2)
Age (yrs)			
Mean	61.9	59.1	61.0
Range	29 - 79	28 - 76	28 - 79
Nerve root compression (%)			
L1	0 (0)	0 (0)	0 (0)
L2	1 (3.6)	1 (7.1)	2 (4.8)
L3	4 (14.5)	2 (14.3)	6 (14.3)
L4	7 (25.0)	2 (14.3)	9 (21.4)
L5	16 (57.1)	9 (64.3)	25 (59.5)